USE OF IMMERSIVE VIRTUAL ENVIRONMENTS FOR MEASURING AND TRAINING SITUATION AWARENESS

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ABSTRACT

Our paper describes the development and preliminary testing of three systems for unobtrusively measuring situation awareness (SA) during dismounted infantry squad-level exercises conducted with immersive Virtual Environment (VE) simulations. The SA measurement systems employ probes administered in the guise of normal radio communications, and systematic subjective ratings of squad leader behaviors and communications. Trials of the systems were conducted with three squads that differed in the experience level of the squad members and whether they had previously functioned together as intact squads. Results indicated that the measurement systems were unobtrusive and measured what they were designed to measure: squad leader SA. Ongoing modifications to the systems are described. Planned applications to other training domains are outlined.

1. INTRODUCTION

Preparing small teams of dismounted infantry for urban operations is one of the greatest military training challenges today (Lampton, Clark, & Knerr, 2003). Dismounted infantry simulations using immersive Virtual Environment (VE) technologies are being developed to support small unit (fire team, squad, and platoon) training; mission rehearsal; and exploration and evaluation of potential changes in doctrine, organizations, equipment, and Soldier characteristics (Campbell, Knerr, & Lampton (2004). The ability to gain and maintain situation awareness (SA) is frequently a critical factor in the success of urban operations. The availability of systems to unobtrusively measure the SA of leaders and teams would not only enhance the effectiveness of VE training systems, but could also contribute to the other VE simulation applications as well.

The SA measurement systems were developed, in part, under an Office of the Secretary of Defense Small Business Innovative Research contract. The Office of Naval Research's Virtual Technologies and Environments (VIRTE) program provided additional funding support for the enhancement and evaluation of the systems (Lampton, Cohn, Endsley, Freeman, Gately, & Martin, 2005).

2. NEW MEASURES OF SITUATION AWARENESS

A three-pronged approach to SA measurement was conceptualized for providing comprehensive assessment of Soldier SA during virtual training and for presenting multiple types of feedback on SA results (Kaber, Riley, Endsley, & Lampton, 2005). This approach includes measuring SA through real-time probes that evaluate soldier SA in terms of perceptions, comprehensions, and projections, along with subjectively assessing SA by capturing expert observer evaluations of Soldier behaviors and team communications.

2.1 Real-time probes

Presentation of real-time probes is a flexible way to assess SA in virtual training scenarios. Probing Soldiers with respect to SA achieved during training is also a highly diagnostic approach which facilitates focusing on several factors associated with infantry SA (Kaber, et al., 2005). Real-time probes involve verbally querying trainees regarding what they know about a given operational situation at the same time they perform required training tasks (i.e., neither the scenario nor training performance is halted for SA data collection). Goal-directed task analysis (GDTA) was used to develop a detailed list of information needs for squads in Military Operations in Urban Terrain (MOUT). The major goals

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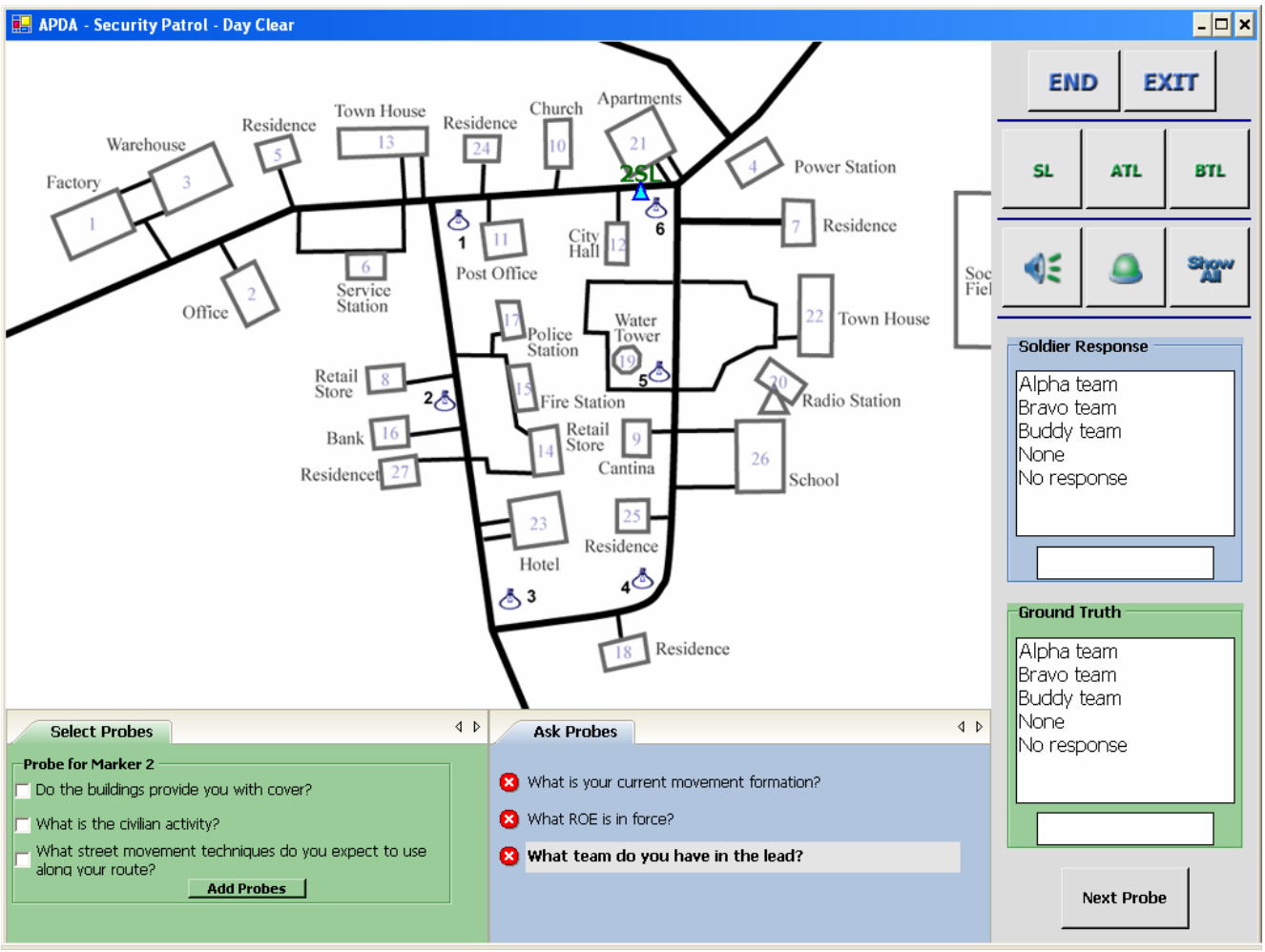

Figure 1. The Automated Probe Delivery Application (APDA).

and critical decisions for the squad were identified, along with the SA (information) elements needed for making the decisions and carrying-out the goals. The GDTA was critical to the development of a robust probe measure in which queries were designed to assess SA on all levels as related to important elements of MOUT such as Enemy, Friendlies, Civilians, Terrain, etc. The GDTA has previously been used as the basis for successful development of query-based approaches to SA measurement (Endsley, 1995; Kaber, Onal & Endsley, 2000).

To implement the real-time probes, we developed the Automated Probe Delivery Application (APDA) which was designed to support a confederate platoon leader in presenting probes to Soldier trainees. The APDA supports probe delivery by tracking the Soldier position in the VE and presenting candidate event- and location-relevant probes to the platoon leader (see Figure 1). The platoon leader selects and poses specific probes to the trainee, so that responses to probes and simulation ground truth can be recorded. Soldier SA is measured in terms of percent correct responses to probes presented during the training trial.

2.2 Team communication and coordination

To measure SA communications we adapted a team communication and coordination measure developed by Brannick, Roach and Salas (1993). The measurement technique involves counting and rating communications representative of critical team behaviors, leadership, decision making, etc. As part of our SA measurement development, the Brannick et al. (1993) measure was modified to focus on SA communications. We analyzed typical squad communications to modify items from the original measure for emphasis on squad leader communications in a MOUT mission. This resulted in a process measure that evaluated squad leader skill in acquiring SA through acquisition and dissemination of information with squad members.

The communications measure, called the SA Measure of Team Communications (SAMTC), requires listening to squad communications through the training system radio

network and rating the quality of trainee statements for target communication items. A running count of "good" and "bad" SA statements is calculated and used at the end of a training scenario for calculating an average score for each communication item and for obtaining an overall team communications score. Figure 2 shows a section of the SAMTC interface.

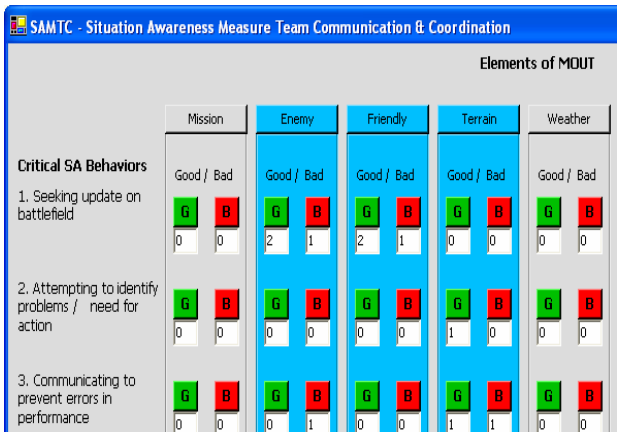

Figure 2. The Situation Awareness Measure of Team Communications (SAMTC)

2.3 Situation Awareness Behavioral Measure

The third component measure involved adaptation of the SABARS (Situation Awareness Behaviorally Anchored Rating Scale) methodology. The SABARS is a post-trial rating technique that requires an observer to evaluate the SA of trainees based on behaviors exhibited during exercises (Matthews, Pleban, Endsley & Strater, 2000). The behavioral items on the SABARS are specific to assessment of platoon leader SA. In order to measure squad behaviors in virtual MOUT training, we modified the items on the SABARS to ensure relevance to squad-level operations. We created an electronic version of the adapted measure, called the Electronic SA Behavioral Measure (ESABM), which allows raters to make multiple ratings on squad physical behaviors during training. An observer watches the squad leader and rates the behaviors on a scale of one (1) to ten (10) for consistency with acquisition and dissemination of SA. This results in an average score for each SA behavior and an overall average score for a given training trial. A section of the ESABM is shown in Figure 3.

3. INITIAL TEST OF THE SITUATION AWARENESS MESUREMENT SYSTEMS

Trials of the three new approaches for measuring SA were conducted at the Soldier Battle Lab (SBL) at Fort Benning. Goals of the initial testing included demonstrating that the systems could measure what they were designed to measure and to ascertain ways to improve the systems.

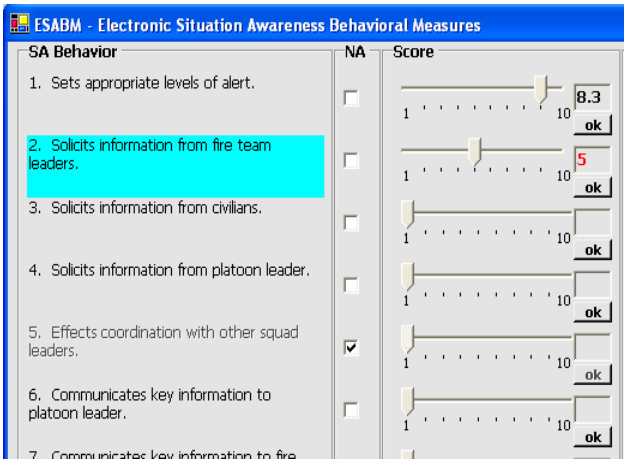

Figure 3. The Electronic Situation Awareness Behavioral Measure (ESABM)

The SBL coordinated the participation of three squads of Soldiers. The squads differed in the amount of previous experience the squad members had in conducting dismounted infantry urban operations and the amount of time they had been together as an intact squad. In fact, one of the squads (Squad 2) was not an intact squad but nine Soldiers of the appropriate grade from the same company. Thus there was some reason to expect that the squads would differ in their initial SA skill levels in the context of urban operations.

Each squad participated for two days. A highly structured train up on the virtual simulators was conducted, followed by building clearing exercises. Each squad then conducted six urban missions in a VE. An After Action Review (AAR) was conducted after each mission. An exit interview was conducted with each squad to collect their views on the mission scenarios and the immersive VE technologies.

Each of the nine Soldiers in a squad was immersed in the Virtual Environment via an SVS system (Figure 4). (At one time SVS was short for Soldier Visualization System, it is now used as a stand alone acronym). A large rear projection screen provided the visual display of the VE. The Soldier's head and weapon were tracked using a hybrid inertial-acoustic tracking system such that when the Soldier knelt or went prone, the virtual view adjusted accordingly. The Soldier navigated through the VE via a thumb switch located on the weapon. Speakers produced spatialized sound with cues to distance and direction. The weapons simulated by the SVSs were varied so that the squad had the typical mix of rifles, squad automatic weapons, and grenade launchers.

Figure 4. The SVS

All of the SVSs were connected to a Distributed Interactive Simulation (DIS) network (Figure 5). Also on the network were: a desktop version SVS for a role player, a Dismounted Infantry Semi-Automated Forces (DISAF) station, and the Dismounted Infantry Virtual After Action Review System (DIVAARS) station.

All of the squad members were on the same radio network. The exercise controller played the role of the mission platoon leader on a separate radio network with the squad leader, integrating the SA probes with normal radio traffic. The exercise controller also directed the activities of the DISAF operator and the Opposing Force (OPFOR) role player. During an exercise the controller would direct the DIVAARS operator to "tag" critical incidents to be noted during the AAR. Finally, the controller served as the AAR facilitator, leading the discussion of what events occurred, why the events occurred, and how to do better on subsequent missions.

One operator at the DISAF station could control dozens of computer generated entities in the VE. Thus, one person could control a sizeable enemy force, friendly units adjacent (in the VE) to the squad being trained, and/or civilians on the battlefield. The desktop SVS for the role player made possible scenario events involving especially complicated behaviors by enemy, friendly, or civilian entities. For example, a local guide could be depicted.

DIVAARS is a PC-based AAR system developed by the Simulator Systems Research Unit of the Army Research Institute for the Behavioral and Social Sciences, and the University of Central Florida's Institute for Simulation and Training. DIVAARS was specifically designed to meet the AAR requirements for dismounted Infantry in urban combat.

The capabilities of DIVAARS include DVD-like replay with synchronized audio and video, indexing to jump to pre-designated segments or views, and tabular data summaries. DIVAARS has the ability to look inside buildings. This function was developed because much of the critical action in urban combat occurs inside buildings. Detailed technical information about DIVAARS is presented by Knerr, Lampton, Martin, Washburn, and Cope (2002).

Separate from the DIS network, two tablet PCs hosted the SAMTC and the ESABM. A desktop computer was used to run the APDA and execute a database application for storing SA data. A touch-screen monitor was integrated with the APDA computer so that the platoon leader could view the position of the squad in the VE and present and record responses to SA probes.

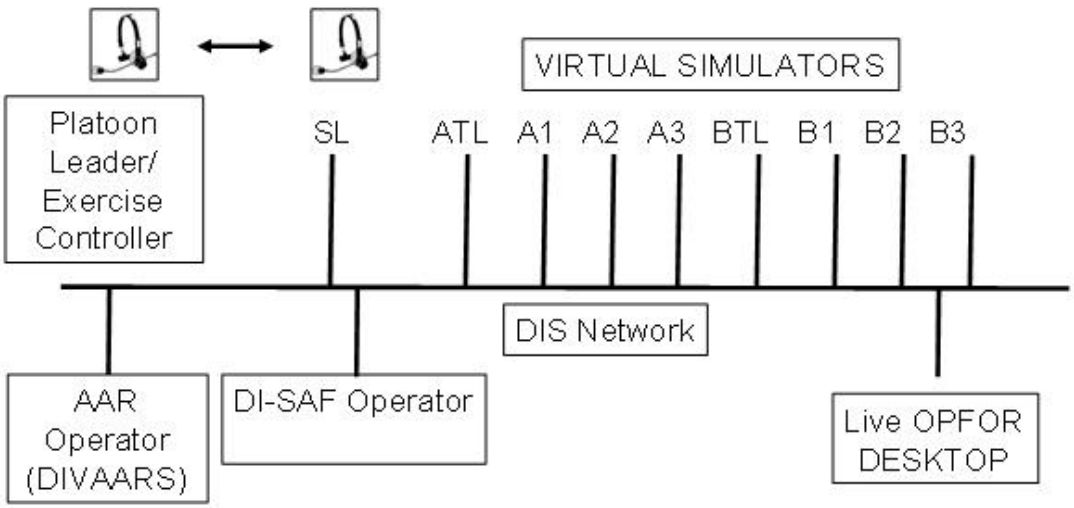

Figure 5. The squad exercise network

The Virtual Environment for the mission exercises was a model of the Shughart-Gordon MOUT training village at Fort Polk. The model consists of about two dozen multi-story buildings with about 300 rooms. The model depicts a hospital, police and other government buildings, a radio station, a factory, warehouses, and administrative and civilian buildings.

The squads performed search (for example, search for arms caches) and security patrols missions. Missions varied in location, time of day (day or night), weather (clear or rain), and the number and skill level of the enemy forces.

Figure 6 shows a DIVAARS display from one of the mission exercises. (The DIVAARS display that the Soldiers view during the AAR differs from the SVS display that they view during an exercise. For example the DIVAARS avatars are less detailed, and show the squad member ID floating above the corresponding avatar.) As can be seen, the squad had to deal with heavy pedestrian and vehicle traffic while conducting the mission.

The exercises averaged about 30 minutes. The AARS averaged about 20 minutes. The AARS covered a variety of topics including movement techniques, reporting, security, and SA.

4. RESULTS AND DISCUSSION

4.1 Accuracy in mission knowledge

Selection, administration, and scoring of the probes did not interfere with the control or tempo of the exercises. The squad leaders readily understood the wording of the probes and interpreted them as mission relevant inquiries from the role player platoon leader.

In general, squad leader overall SA as assessed through real-time probing was high, ranging from approximately 83% to 96%. It appeared that the leaders for intact squads (Squads 1 and 3) might have performed better in the arms cache discovery scenario, as compared to the security patrol, but we did not observe statistical significance in this finding. Individual differences in SA across trials were substantial.

4.2 Mission behaviors

We observed significant differences in squad leader behaviors across the squads. Pairwise comparisons of the data on the squad leaders revealed significant differences ($p < 0.05$) among all leaders, with the squad leader of Squad 1 producing the highest SA behavior scores and the leader of Squad 2 producing the lowest. The trend appears to correspond with squad leader experience and training

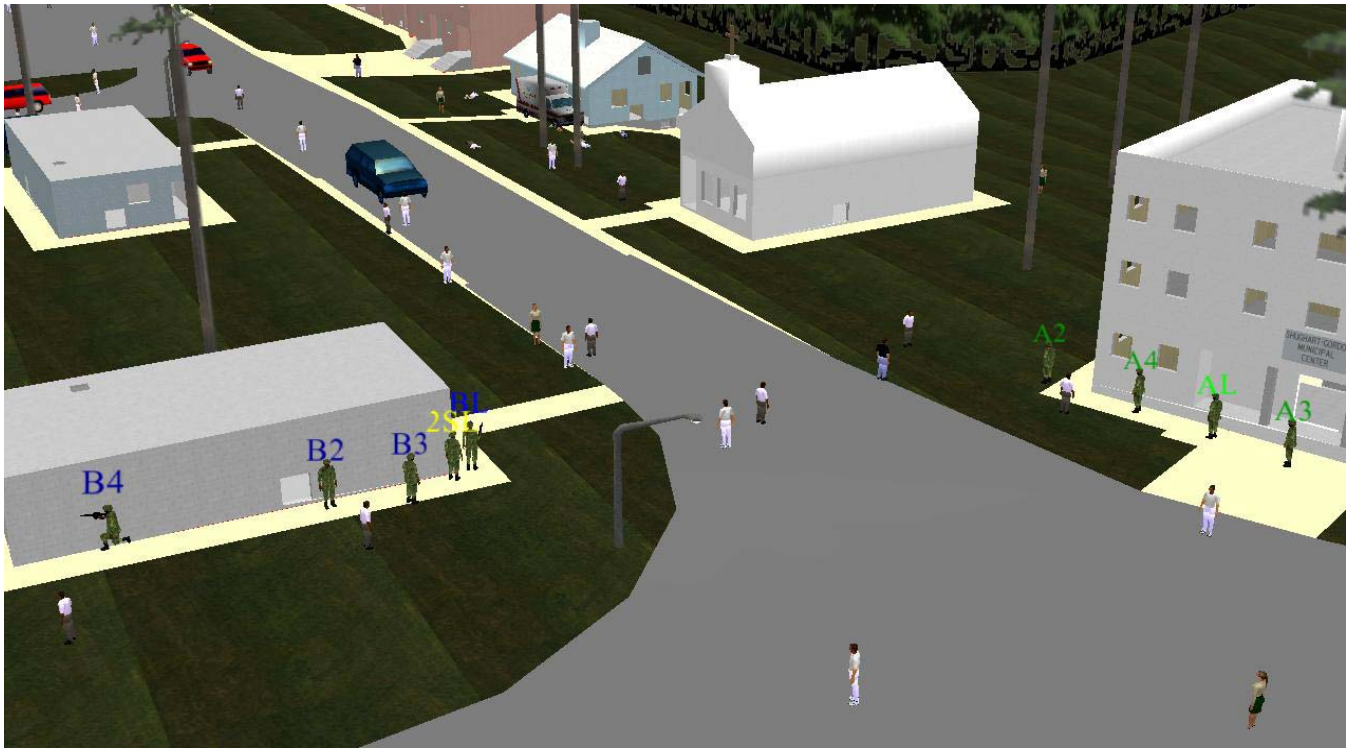

Figure 6. Mission exercise displayed by the After Action Review system

levels which were determined by interviews. Figure 7 presents a plot of the overall ratings of squad leader SA behaviors. On average, we found the behaviors of all squad leaders to be more consistent with good SA in the arms cache search versus the security patrol scenarios; however, we did not observed statistical significance of this finding through our non-parametric analysis. In general though, the ESABM provided an excellent opportunity for behavioral data collection. The number of behavior observations that were made by the expert raters was considered sufficient for reliable analyses of Soldier SA in each scenario.

4. 3 Quality of team communications

In regard to the team communications measure of SA, we observed significant differences in team communication and coordination across squad leaders. Pairwise comparisons of the data on the various squad leaders revealed significant differences ($p < 0.05$) among all leaders. As with the ESABM results, these differences in communication quality appeared to correspond with the military experience levels of the squad leaders with the less experienced leader of Squad 2 being rated far worse than the others. See Figure 8.

4.4 Immersive Virtual Environment technologies and training

It is possible that the VE training approach we employed would be of relatively more value to squads with less previous training and experience than the squads that supported this research. However, even the most experienced squad expressed the view that the exercises were interesting and led to valuable discussions during the AARs. There was a general consensus that this type of VE training would be of great value to inexperienced squad leaders and squads in preparation for training at live urban training sites.

In pleasant contrast to the early years in VE training research, the individual immersive simulators and networked components operated almost flawlessly. The rear projection screen systems allowed the data collectors to easily determine what the squad members were seeing and doing. The extremely fast pace of urban operations

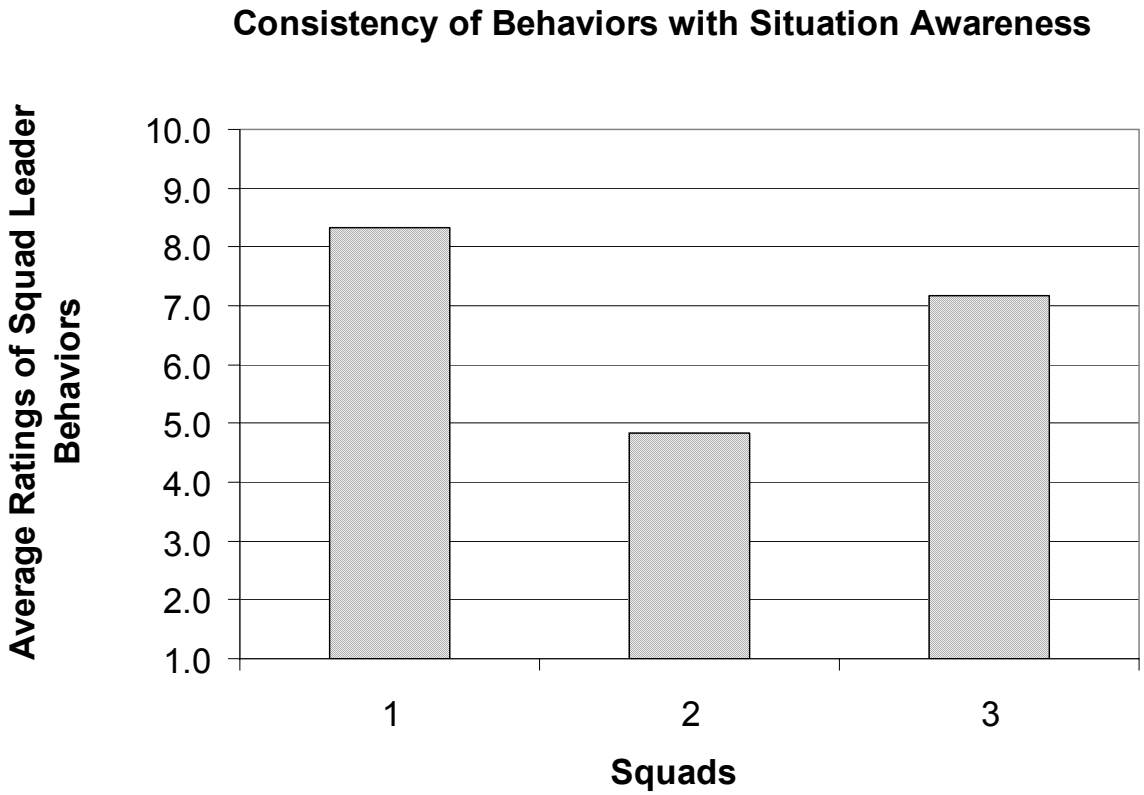

Figure 7. Average SA behavioral ratings for each squad leader across all mission exercises

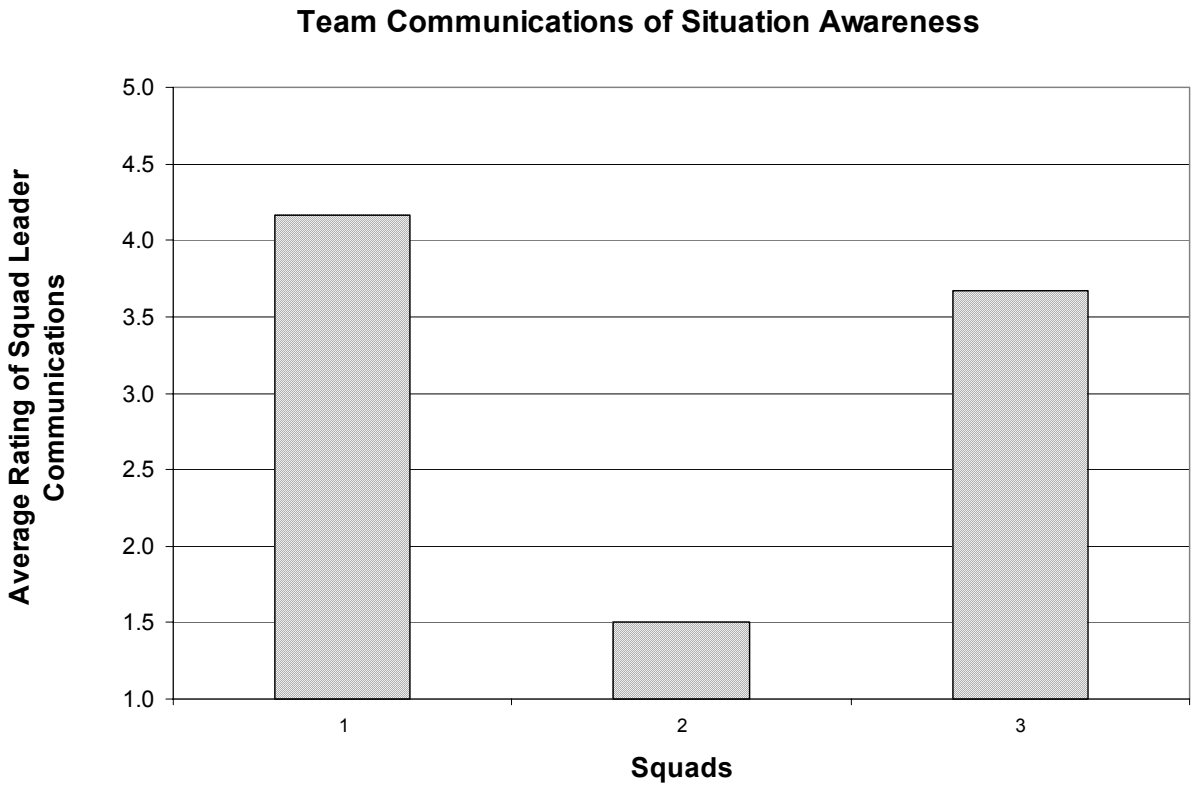

Figure 8. Average SA communications ratings for each squad leader across all mission exercises

sometimes challenged the DISAF operator and the OPFOR role player in precisely creating the desired tactical situations scripted in the mission scenarios. However, one of the advantages of simulation is that we could always readily determine ground truth.

5. FUTURE WORK

The SA measurement systems are being modified so that the content and format are optimized from the perspective of providing performance feedback to the squad members during the AAR. In addition to effective feedback, another goal is to have the feedback available to support an AAR within 30 minutes after the completion of an exercise.

The successful demonstration of the SA measurement systems is resulting in programs to adapt the systems to a variety of other training domains. As part of the Office of Naval Research's Virtual Environments and Technologies (VIRTE) program, the SA measurement systems are being adapted for application to Fire Support Team (FiST) training. The systems are also being adapted for a new program of simulation-based training being developed for the Federal Law Enforcement Training Center.

6. SUMMARY AND CONCLUSIONS

Three systems for unobtrusively measuring situation awareness (SA) during dismounted infantry squad-level exercises conducted with immersive Virtual Environment (VE) simulations were successfully demonstrated in trial runs with experienced squads. Results indicated that the measurement systems were unobtrusive and measured what they were designed to measure: squad leader SA. The systems are being modified based on the results and applied to other training domains.

ACKNOWEDGMENTS

All statements expressed in this paper are those of the authors and do not necessarily reflect the official opinions of the U.S. Army Research Institute or the Department of the Army.

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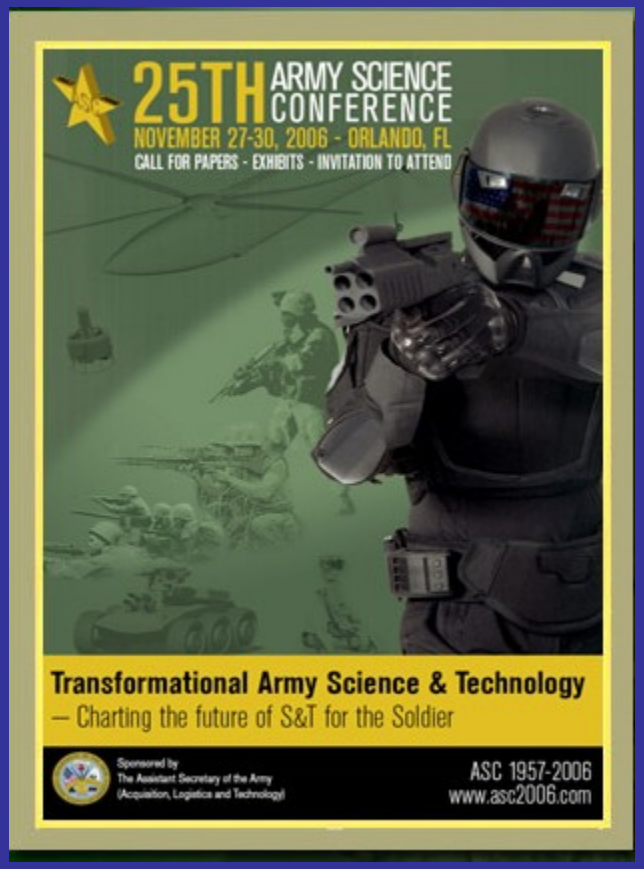


Overview

- Dismounted Infantry simulation for preparing small teams for urban operations
- An OSD/Army Small Business Innovative Research (SBIR) system for measuring squad Situation Awareness
- Collaboration with the Office of Naval Research, Virtual Technologies and Environments (VIRTE) program
- Spiral development trials at the Soldier Battle Lab, Fort Benning
- Results and Future Activities

Preparing small teams of Dismounted Infantry for urban operations is one of the greatest challenges for the simulation community.

- Training
- Mission Planning and Rehearsal
- Concept Testing

Situation Awareness

The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.

	Theory	Squad Level
Level 1	Perception	What?
Level 2	Comprehension	So what?
Level 3	Projection (near future)	Now what?

Why Situation Awareness?

- Is of proven value in other areas for performance diagnostics and training feedback

- Is a fundamental requirement for success on the modern battlefield

- An unobtrusive measure of SA could strengthen the application of Dismounted Infantry simulation.

Unobtrusive Measurements

- Objective, real-time probing of knowledge of the operational situation:

  Semi-automated probe presentation and unobtrusive delivery during normal operational communications

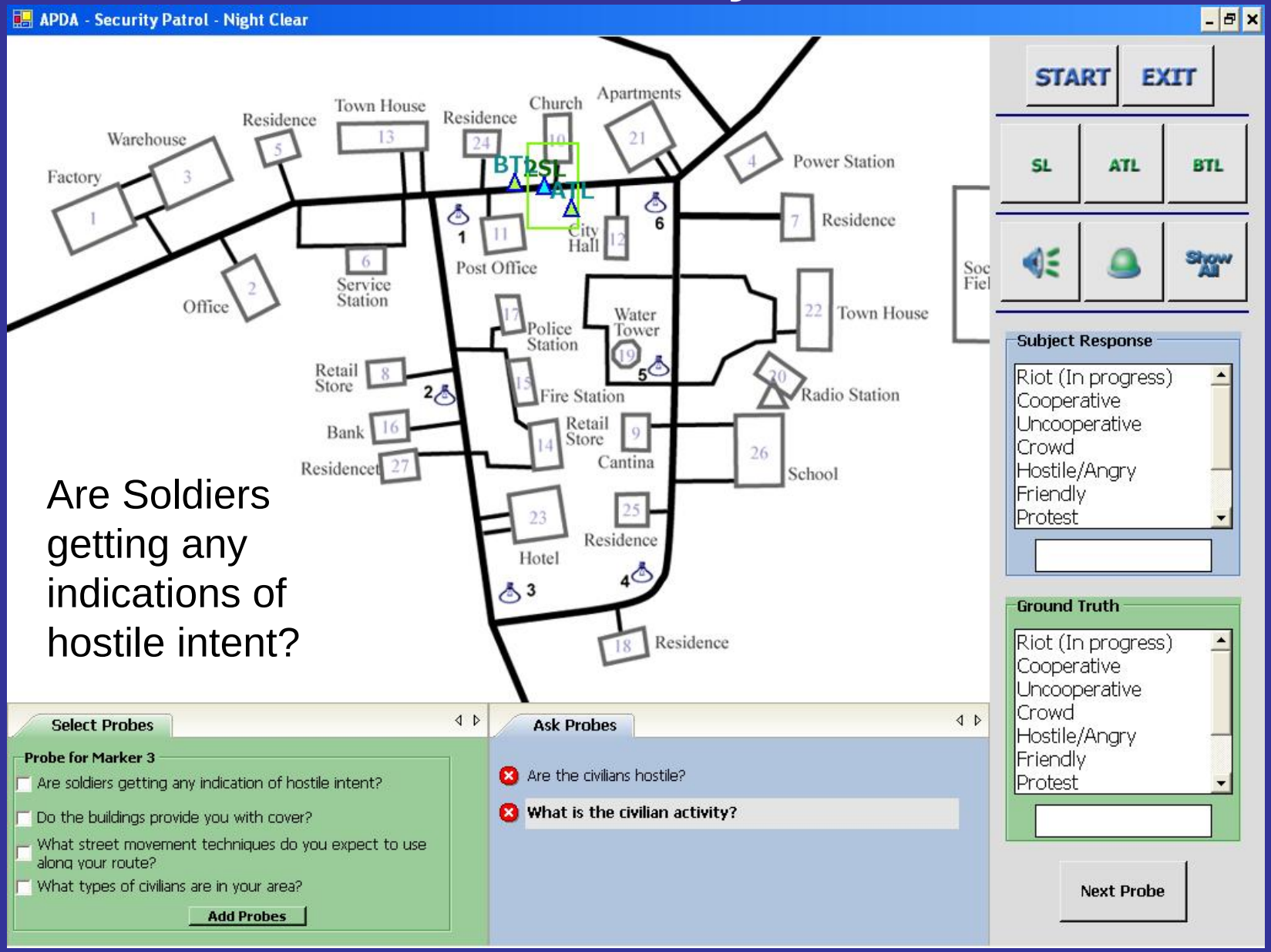
- Subjective, online ratings of Soldier behaviors:

  Assessment of squad leader behaviors for consistency with acquisition/dissemination of SA to squad

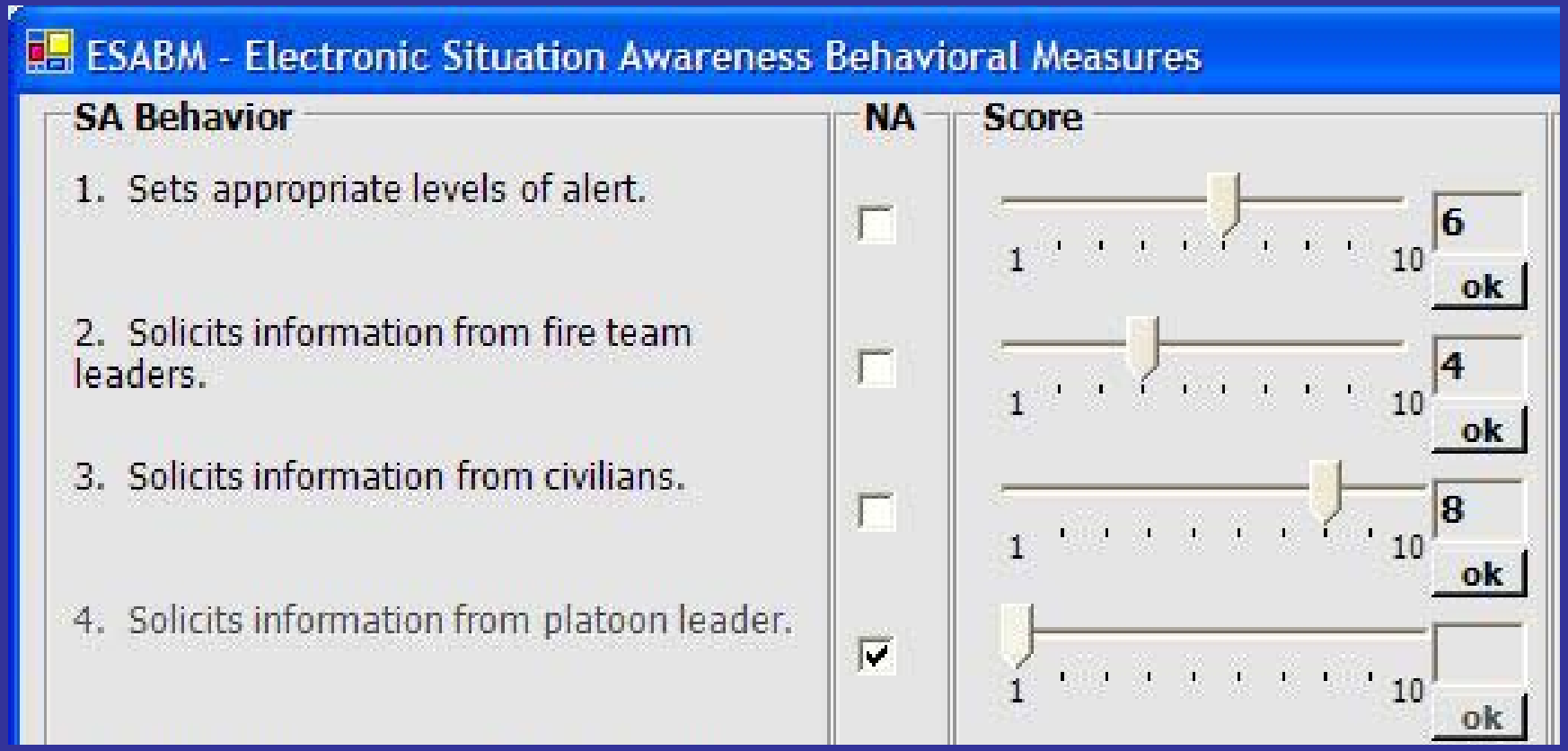
- Subjective, online ratings of team communications:

  Assessment of commo on various MOUT elements

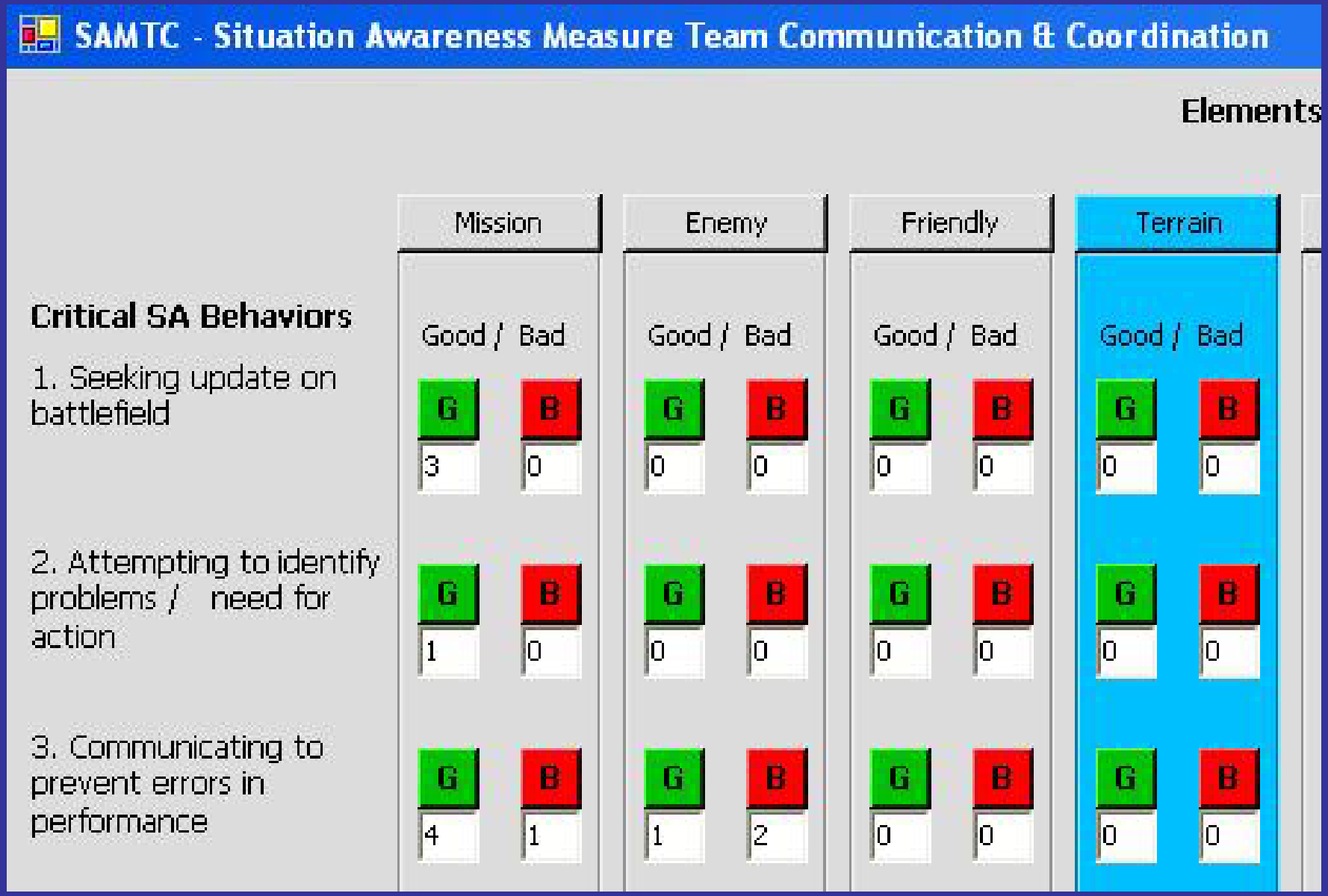
SA Probe System



Electronic Situation Awareness Behavioral Measures



Team Communications Measure



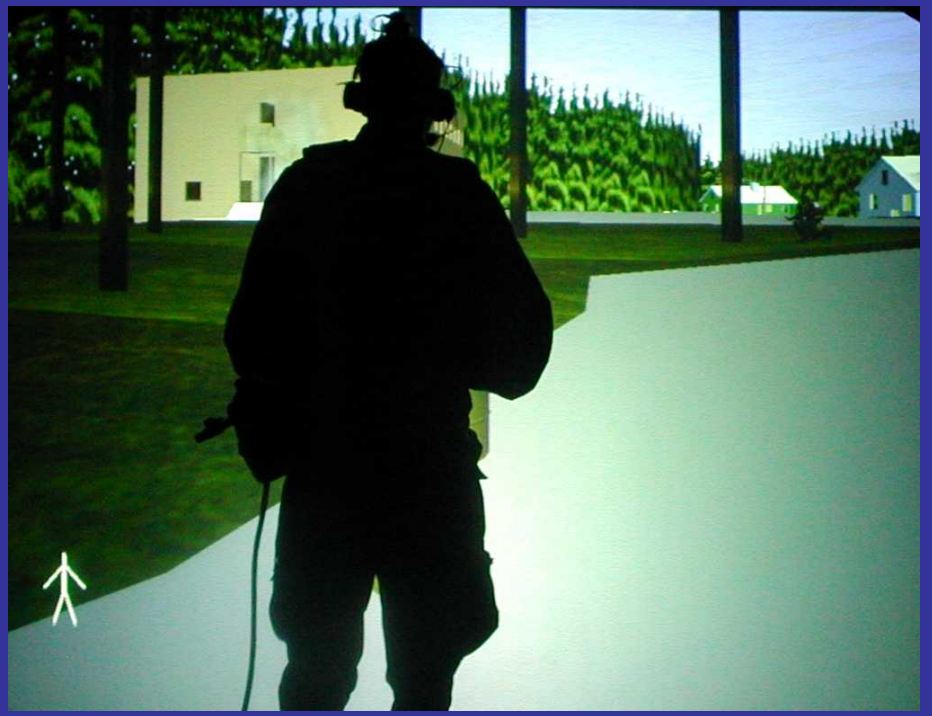
Soldier Battle Lab Assessment

3 squads (two days each):

- **Systematic train-up on immersive simulators**
- **3 building clearing exercises**
- **6 MOUT exercises (3 patrol, 3 search)**
- **After Action Review for each exercise**
- **Exit interview**

Soldier Visualization Station (SVS)

- Rear Screen Projection
- Tracks Head and Weapon Position
- Thumb Switch Used for Locomotion
- Simulated Radio Communications
- Array of Weapon Types
- Fragmentation, Concussion, & Smoke Grenades
- Wounding



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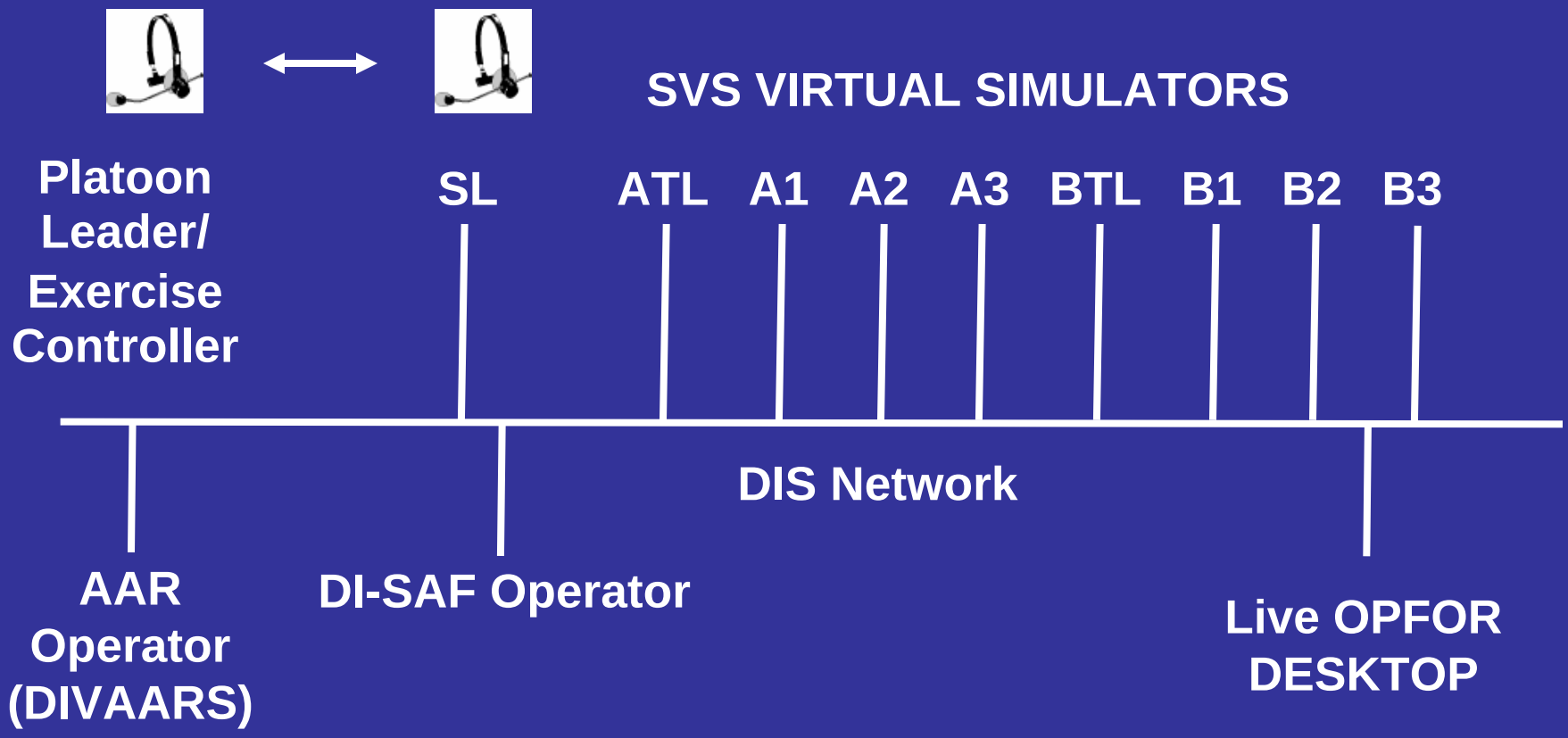
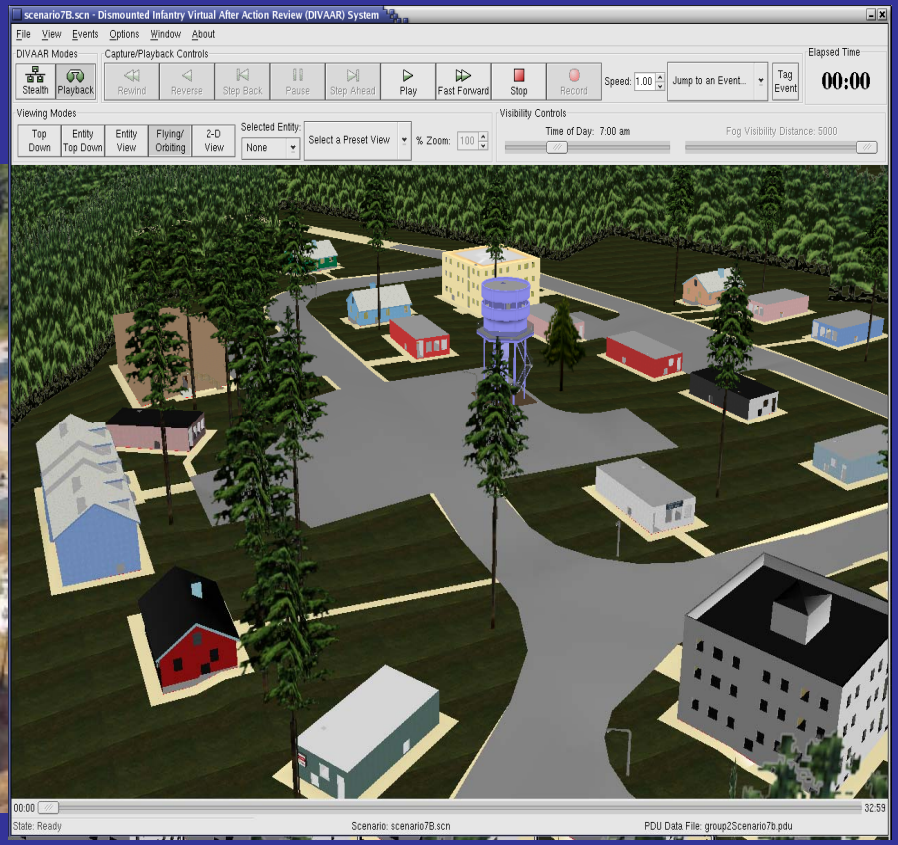
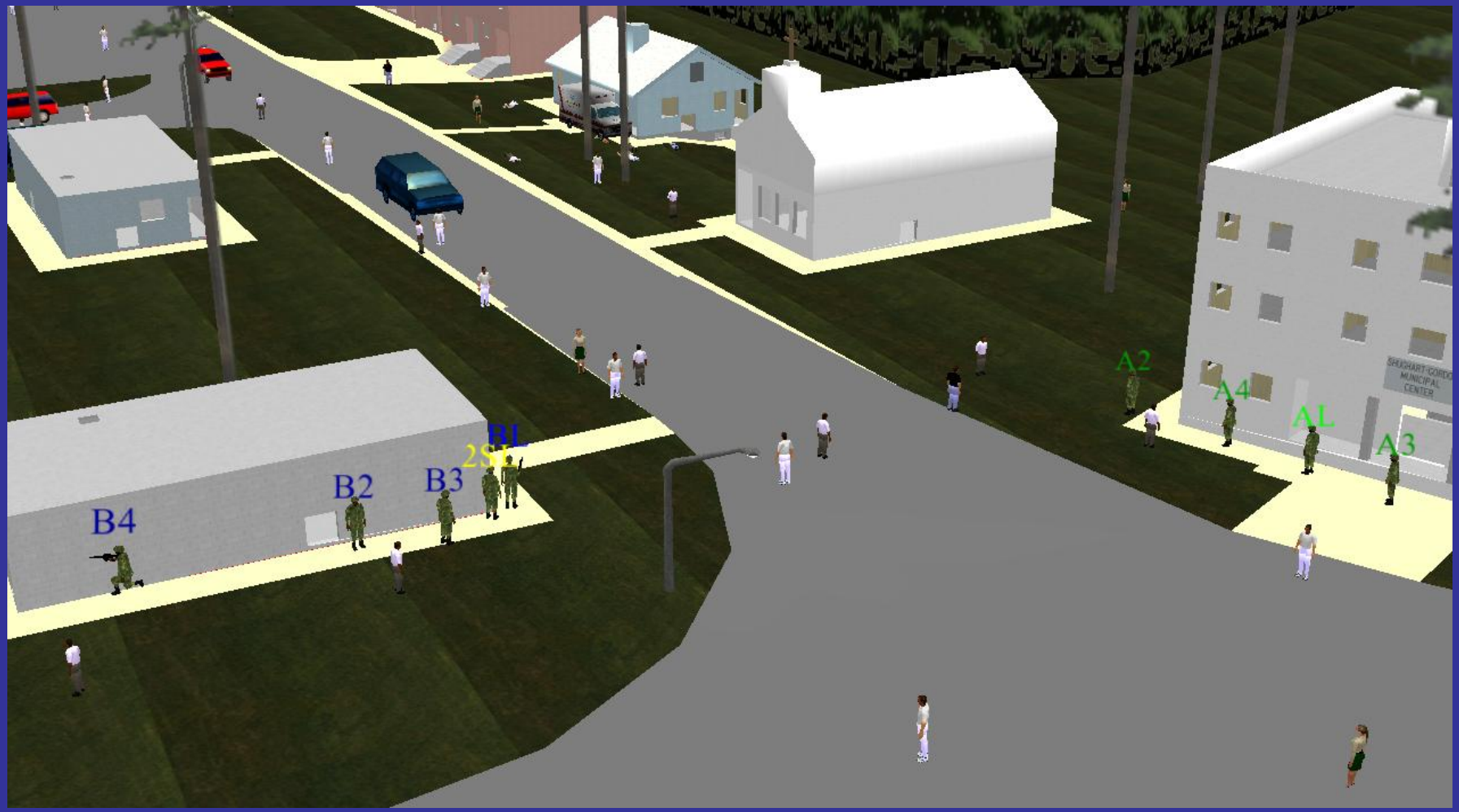
VE System for Squad Training



Shughart-Gordon Village

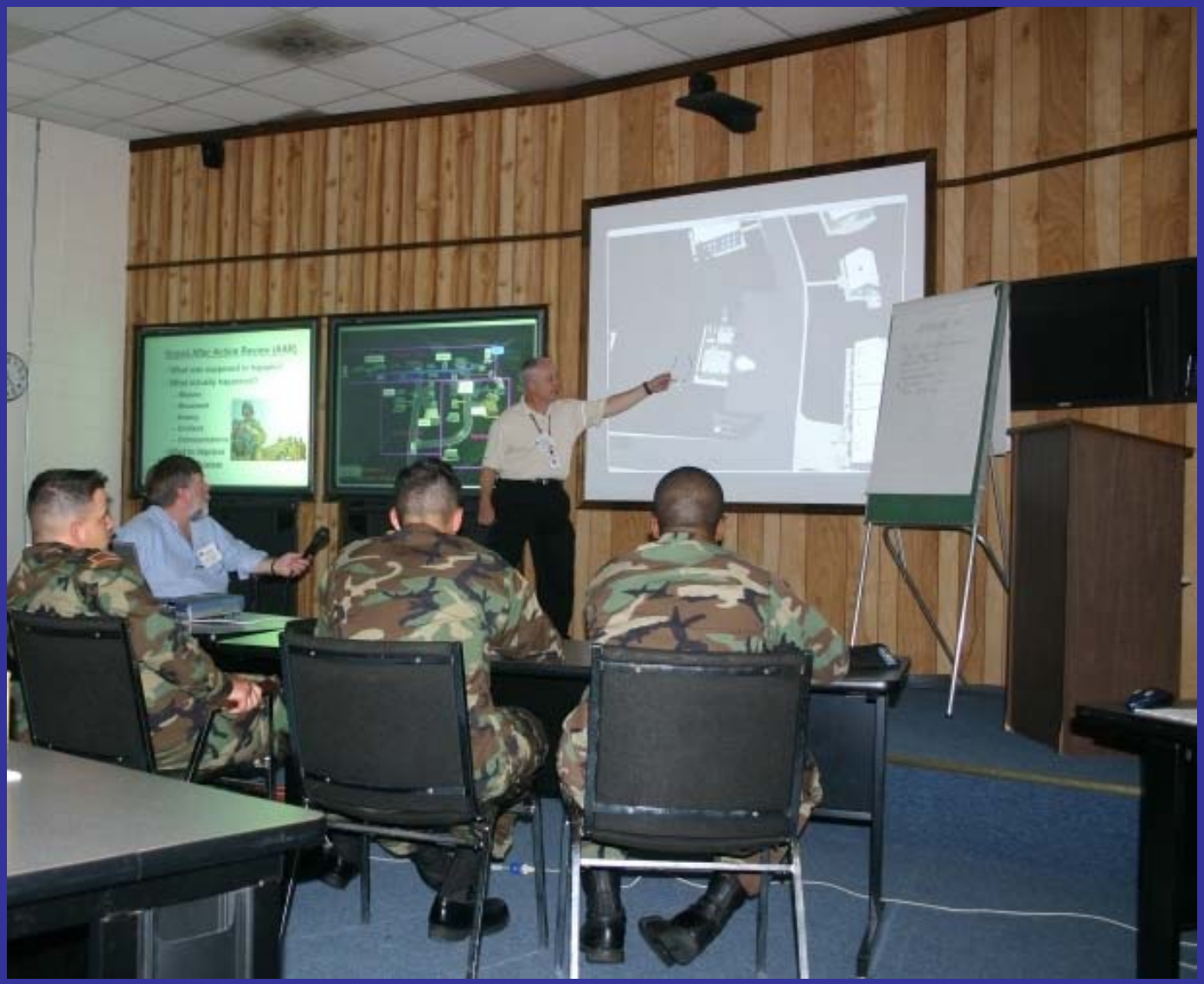


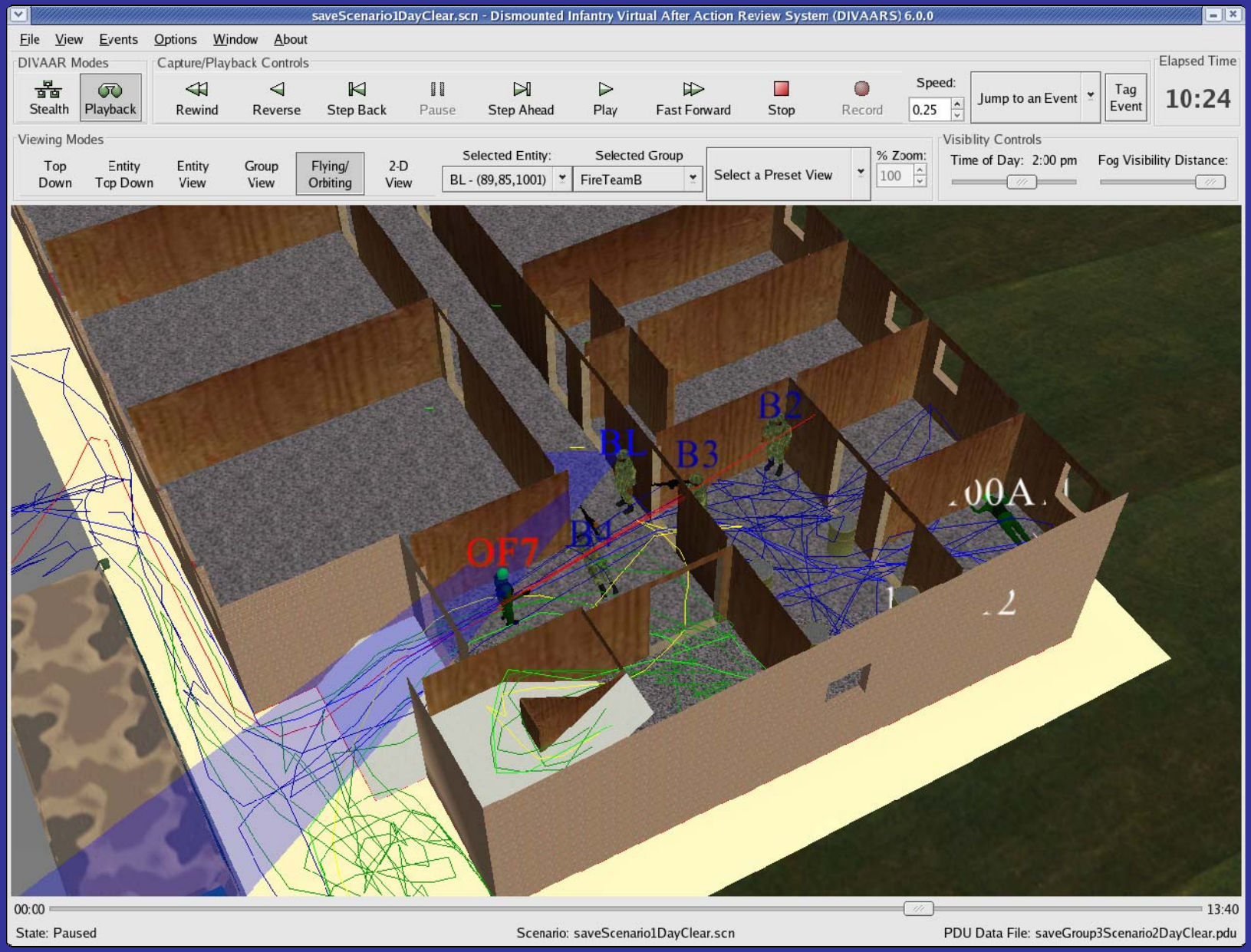
Mission Exercise



100ASL
AL
B4
A2
CENTER CITY
FIRE-RESCUE
Advanced Life Support

After Action Review

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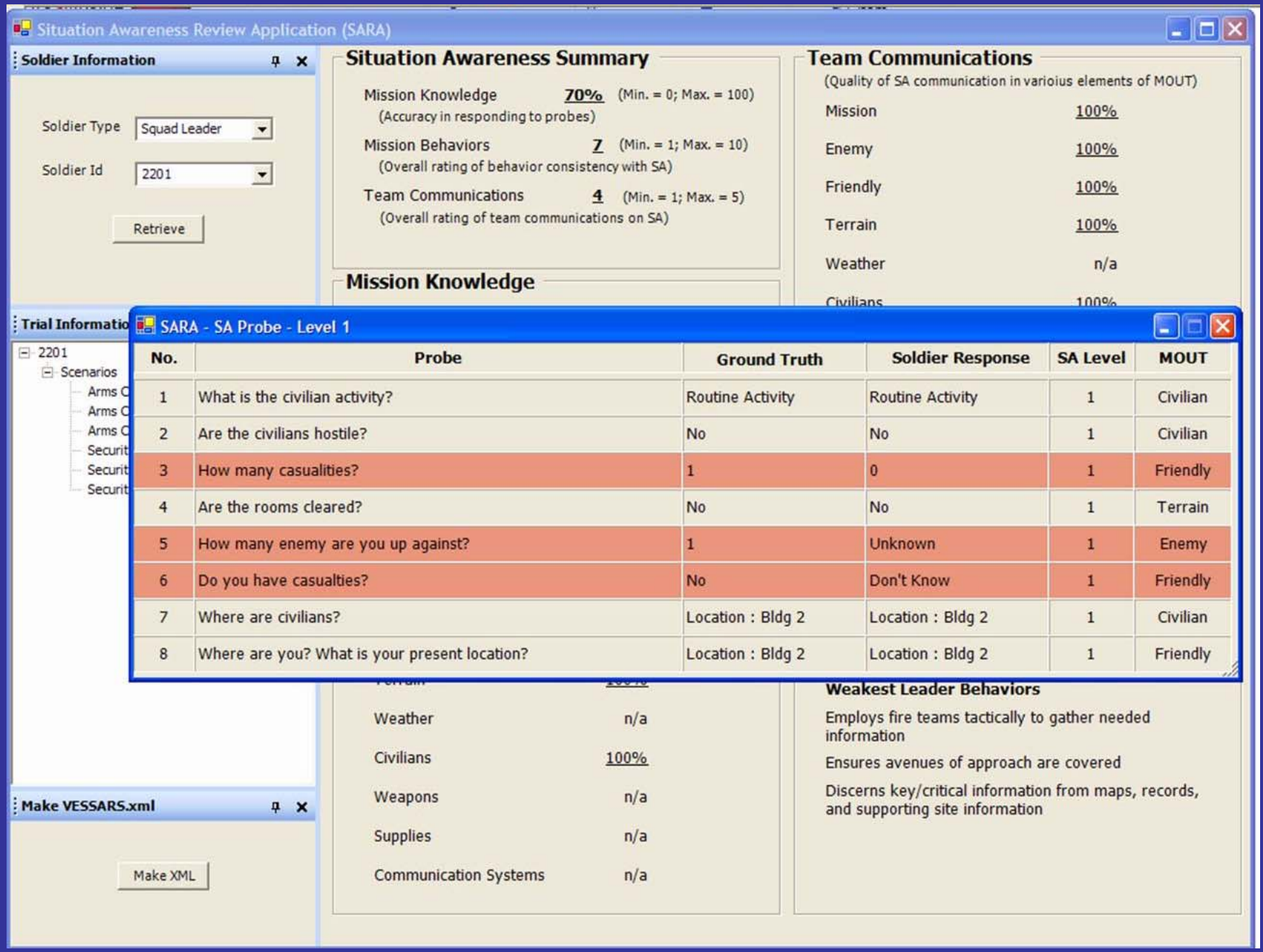
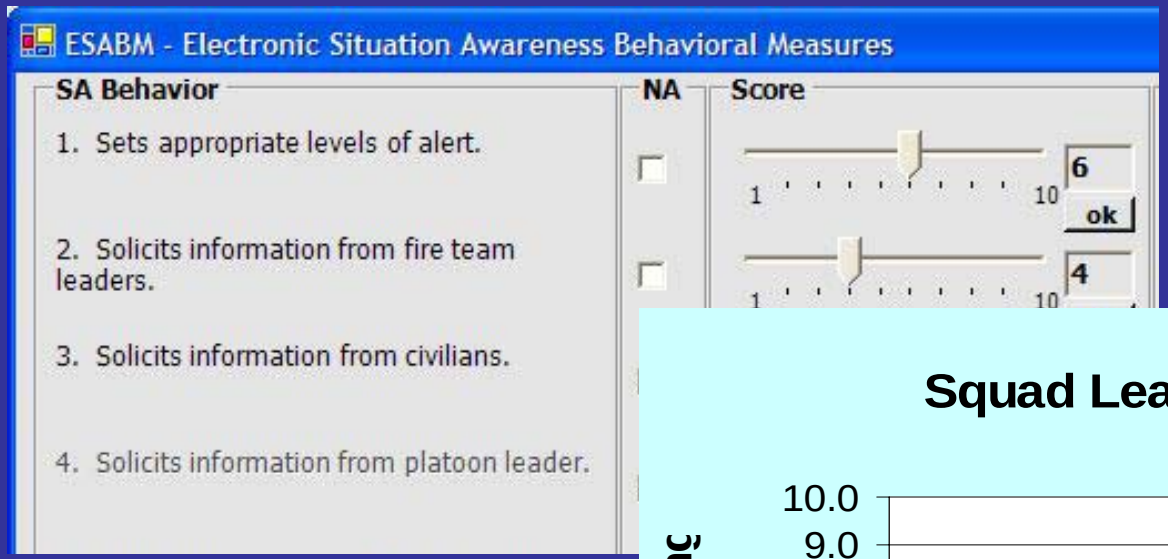
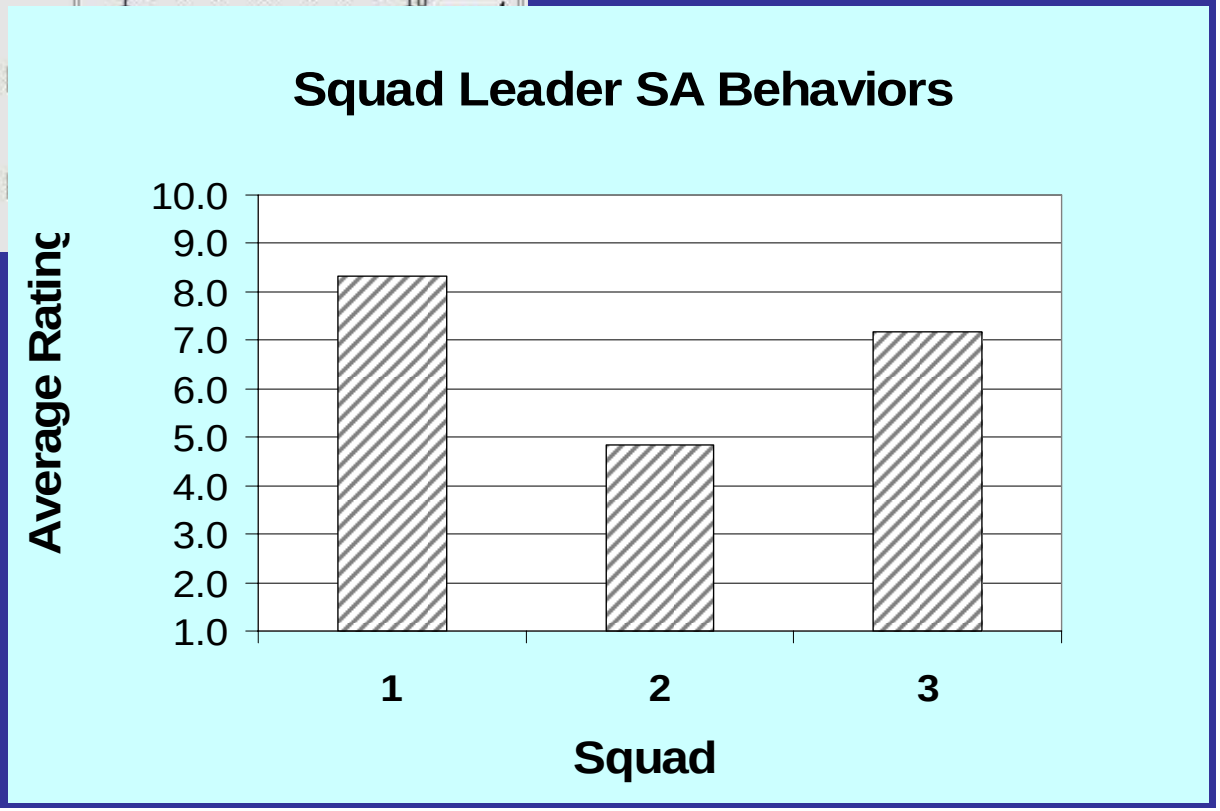
Stealth
Playback
Capture/Playback Controls
Rewind
Reverse
Step Back
Pause
Step Ahead
Play
Fast Forward
Stop
Record
Speed:
0.25
Jump to an Event
Tag Event
Elapsed Time
10:24
Viewing Modes
Top Down
Entity Top Down
Entity View
Group View
Flying/ Orbiting
2-D View
Selected Entity:
BL - (89,85,1001)
Selected Group
FireTeamB
Select a Preset View
% Zoom:
100
Visiblity Controls
Time of Day: 2:00 pm
Fog Visibility Distance:
B2
BL
B3
OF7
00:00
13:40
State: Paused
Scenario: saveScenario1DayClear.scn
PDU Data File: saveGroup3Scenario2DayClear.pdu

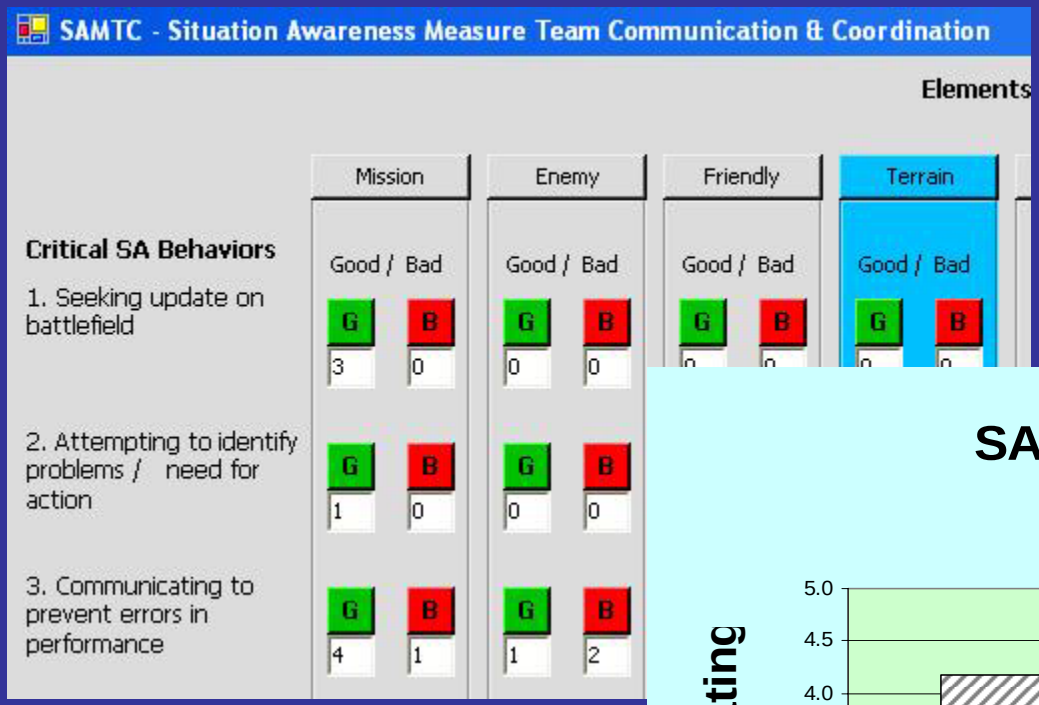

Situation Awareness Review Application (SARA)
Soldier Information
Soldier Type
Squad Leader
Soldier Id
2201
Retrieve
Situation Awareness Summary
Mission Knowledge 70% (Min. = 0; Max. = 100)
(Accuracy in responding to probes)
Mission Behaviors 7 (Min. = 1; Max. = 10)
(Overall rating of behavior consistency with SA)
Team Communications 4 (Min. = 1; Max. = 5)
(Overall rating of team communications on SA)
Team Communications
(Quality of SA communication in varioius elements of MOUT)
Mission 100%
Enemy 100%
Friendly 100%
Terrain 100%
Weather n/a
Civilians 100%
Mission Knowledge
Trial Information
2201
Scenarios
Make VESSARS.xml
Make XML
Weather n/a
Civilians 100%
Weapons n/a
Supplies n/a
Communication Systems n/a
Weakest Leader Behaviors
Employs fire teams tactically to gather needed information
Ensures avenues of approach are covered
Discerns key/critical information from maps, records, and supporting site information
SARA - SA Probe - Level 1
No. Probe Ground Truth Soldier Response SA Level MOUT
1 What is the civilian activity? Routine Activity Routine Activity 1 Civilian
2 Are the civilians hostile? No No 1 Civilian
3 How many casualities? 1 0 1 Friendly
4 Are the rooms cleared? No No 1 Terrain
5 How many enemy are you up against? 1 Unknown 1 Enemy
6 Do you have casualties? No Don't Know 1 Friendly
7 Where are civilians? Location : Bldg 2 Location : Bldg 2 1 Civilian
8 Where are you? What is your present location? Location : Bldg 2 Location : Bldg 2 1 Friendly

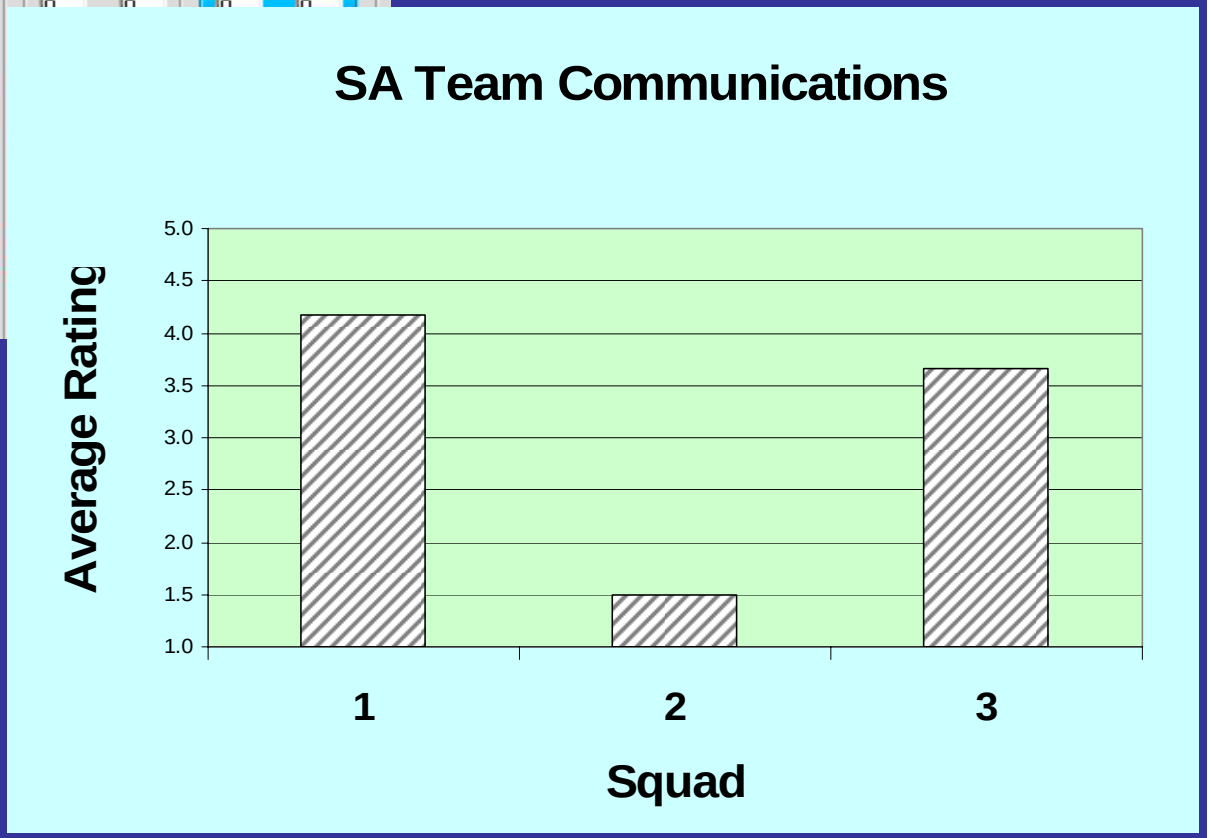
Electronic Situation Awareness Behavioral Measures





Team Communication Measure





Future Activities

- **Adapting the three SA measurement systems (probe, behaviors, and commo) to Fire Support Team (FiST) training under the ONR VIRTE program**
- **Applying SA measurement to tasks trained by the Federal Law Enforcement Training Center (FLETC)**
- **Adapting SA measurement to Massively Multiplayer Online Gaming systems for training Dismounted Infantry and Close Air Support (CAS)**